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Thijs Jong, Oscar Couwenberg, and Edwin Woerdman

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European University Institute

Badia Fiesolana

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Abstract

The aim of this paper is to examine whether shareholders consider the EU Emissions Trading Scheme (EU ETS) as value-relevant for the participating firms. An analysis is conducted of the share prices changes as caused by the first publication of compliance data in April, 2006, which disclosed an over-allocation of emission allowances. Through an event study, it is shown that share prices actually increased as a result of the allowance price drop when firms have a lower carbon-intensity of production and larger allowance holdings. There was no significant value impact from firms' allowance trade activity or from the pass-through of carbon-related production costs (carbon leakage). The conclusion is that the EU ETS does 'bite'. The main impact on the share prices of firms arises from their carbon-intensity of production. The EU ETS is thus valued as a restriction on pollution.

Keywords

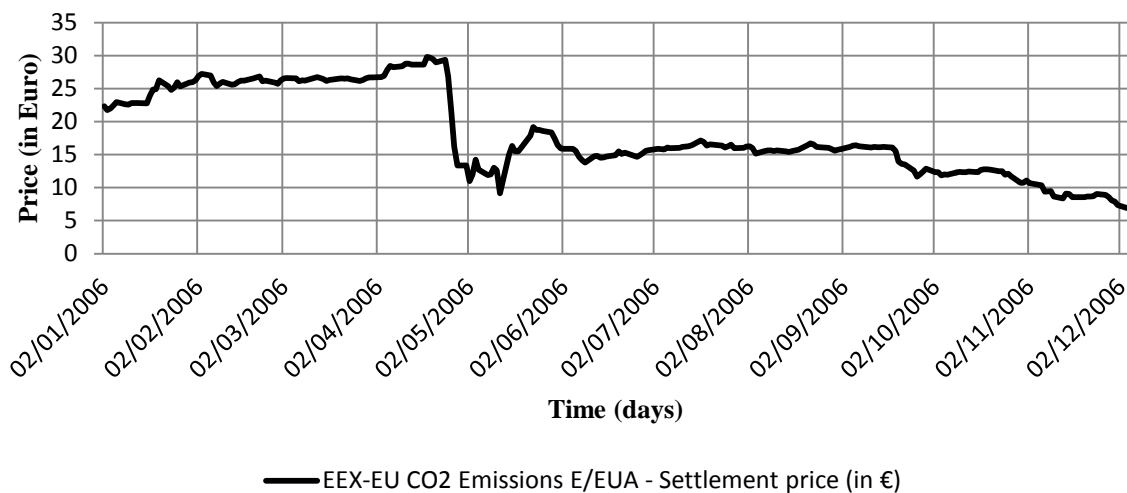
Climate change regulation; emissions trading; EU ETS; event study; share prices; over-allocation; allowance purchases and sales

1. Introduction*

To meet its greenhouse gas emission targets, the European Union (EU) has introduced in 2005 the so-called EU Emissions Trading Scheme (EU ETS). This scheme is based on “cap-and-trade” regulation. The total amount of emissions is ‘capped’ and the EU emission allowances, which make up the subsets of that total amount, are tradable. If the transactions costs are low, allowances will end up in the hands of those users who value them the most. Hence, the emissions cap will be met in a cost-effective way – which is one of the principle reasons why the EU has embarked on this policy (see e.g. Directive 2003/87/EC Article 1).

This paper studies the over-allocation of emission allowances in the EU ETS in 2006. Before the start of the EU ETS, the total domestic supply of allowances was determined through National Allocation Plans (NAP). However, at the end of April 2006 the first EU Member State annual reports were published. These reports showed that national demand for allowances in 2005 was much less than supply. The resulting carbon price drop was the main signal that market participants revised their expectations on the shortage of allowances (see Figure 1).

Figure 1: The EU ETS April 2006 carbon price drop



With a supply larger than the demand for allowances, it is expected that the carbon price will be equal to zero. Since investors take into account the cost of regulation in their valuation of firms, they are supposed to have discounted this development from the EU ETS. As polluting will be costless with

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demand smaller than supply, it is expected that investors put a higher valuation on dirty firms relative to clean firms.

However, Figure 1 shows that the carbon price did not immediately fall to zero. Moreover, the statistics (to be shown later) suggest that investors put a higher valuation on cleaner firms instead. The aim of this paper is therefore to find out whether investors consider the EU Emission Trading Scheme (EU ETS) as relevant for polluting firms, and how this is related to the firms' allowance allocations and transactions.

Therefore, the central question of this paper is: Did EU ETS firms' shareholders interpret the carbon price drop of April 2006 as significant and, if so, how did the event's impact differ among firms' allocations and transactions? Insights from this analysis will also be useful for the current situation of the EU ETS. Again, the demand for allowances has not kept up with supply, resulting in an allowance price which in early 2013 reached a level below € 3 Euro per tonne of CO₂.

This paper is organized as follows. In Section 2, the literature will be reviewed on the EU ETS whether, and if so, how the impact of the EU ETS differs through the related allocations and transactions. It appears that the literature is unequivocal on what the impact is, and that an integrated view on the differential effects from allocations and trade on share prices is missing. In Section 3, hypotheses are formulated through which the carbon price drop should have impacted the EU ETS firms as a function of allocations and transactions. The methodology will be discussed in Section 4. The empirical results and a discussion thereof will be presented in Sections 5 and 6, respectively. Section 7 concludes the paper.

2. Literature review

In Phase I (2005-2007) the expected total supply of allowances ended up being higher than the demand for allowances. Yet this did not imply that the scheme was not cost-effective; if polluting will be costless it simply will not affect a firm's management or its share prices. Anger and Oberndorfer (2008) have shown for a sample of German firms that, albeit for 2005 only, allocations did not impact revenues and employment. Moreover, Kettner et al. (2008) concluded that it was rather unlikely that abatement had taken place.

However, ex-post research shows that the EU ETS did have an impact on firms and their behavior. Trotignon and Delbosc (2008) showed that in many countries the possibility of borrowing had been used which, at least before the April 2006 carbon price drop, was a good strategy to prevent buying expensive allowances¹. Furthermore, Anderson and Di Maria (2011) showed there were both 'under-allocations' as well as 'over-allocations', and that some firms did reduce emissions. Indeed, Abrell et al. (2011) found that the profit margins of over-allocated firms were positively affected while those of under-allocated firms were negatively affected. They also found that in the transition of Phase I and Phase II (2008-2012), relatively more pollution was abated by firms which were under-allocated than firms which were over-allocated.

Furthermore, through the April 2006 carbon price drop, Bushnell et al. (2011) showed that also the market valuations of firms were responsive to the EU ETS. The overall impact from the carbon price drop was negative. The reasoning is that with the carbon price reflected in the product price, the new (lower) product price decreases revenues and, hence, the profits of firms. This impact appeared to be different among two groups of industries: the energy industry and the remaining industries under the

¹ This feature allows firms to make use of any allowances from their year $T+1$ allocation for their year T emissions. It will be further elaborated in Section 4.3.

EU ETS.² Bushnell et al. (2011) found that market values of *cleaner* energy firms decreased more than those of *dirtier* energy firms. And since the energy industry was short on allowances, i.e. it had more emissions than allocated allowances, they argued that dirtier energy firms must have reaped more carbon cost savings – through the carbon price drop – relative to the value declines of their (larger) allowance holdings than cleaner energy firms did. The opposite was the case for the remaining non-energy industries. These were long on allowances, i.e. they had fewer emissions than allocated allowances. And since the authors found that the market values of *dirtier* industries declined more than those of *cleaner* industries, for dirtier industries the value declines of their (larger) allowance holdings must have been higher than their carbon cost savings.

This study contributes to the literature through the inclusion of the firms' allowance purchases and sales from the EU ETS database: the Community Independent Transaction Log (CITL). To our knowledge the impact of firms' EU ETS allowance transactions on share prices has not been analyzed yet. Drawing on 2005 and 2006 EU ETS transactions, Jaraitė and Kažukauskas (2012) analyze the determinants that affect the likelihood of firms selling their allowances. Among others, allocation amounts but also differences in allocations-to-emissions positively affect this likelihood to sell. The latter seems to run counter to the finding in Ellerman and Trotignon (2009) that firms in the EU ETS traded less if they were long on allowances, and traded more if they were short on allowances. Given these results one would expect that the determinants of selling differ from the determinants of purchasing allowances. Through an extensive analysis on the trading of allowances, Zaklan (2013) shows that these determinants indeed differ. However, for some of the sales determinants in Jaraitė and Kažukauskas (2012), Zaklan (2013) finds notable divergent effects concerning, e.g., the allowance allocation size and the firms' turnover.

The literature thus shows that the ex-post results are mixed on the impacts of over-allocation, on the interrelation between allowance allocations and trading patterns, and that there is a literature gap regarding the effects of allowance trade on share prices. This paper fills these gaps by including the effects of allowance trade in the estimation of the allocation and product market effects on EU ETS share prices. In the next section hypotheses are formulated on the interplay of these three factors.

3. Theoretical framework and hypotheses

In the EU ETS tradable allowances are allocated to polluting firms, such as energy companies, steel makers and cement manufacturers. Depending on the allocation rules, they either receive their allowances for free or they have to buy them at auction, and they either receive a large or small number of allowances. Auctioning or free allocation have similar economic costs (costs of buying allowances or the opportunity costs of using free allowances) but do effect accounting profits and the market value of firms differently (Woerdman et al., 2009). A firm with free allowances has a higher market value than a comparable firm that had to buy its allowances at auction. Free allocation was the dominant form in Phase I, also called “grandfathering”, which refers to allowances being allocated based on historical emission levels.

By trading allowances a price tag is attached to the emissions, which has an impact on the profits and thereby the value of the firms. For instance, if the allowance price increases, this impacts the profits of the firms negatively, having a negative effect on the share price. In reality a number of effects come up simultaneously. The three main effects, discussed below, are: (1) carbon leakage and carbon intensity effects, (2) exposure and borrowing effects, and (3) trade effects.

² In the remainder of the text, we use the “energy” sector, the “Power & Heat” sector, and the “power” sector for the same industry.

3.1 Carbon leakage and carbon-intensity effects

Because fossil fuels become less attractive in an emissions trading scheme, the use of fossil fuels and thus emissions may actually increase in countries without an emissions trading scheme. ‘Carbon leakage’ refers to the consequential relocation of companies, and thus emissions, to countries without an emissions trading system – i.e. where restrictions on carbon emissions are weaker.

Carbon leakage impacts the competitiveness of firms bound by an emissions trading system. Those firms competing with firms from outside the system cannot or can only partly pass on carbon-related costs in their product prices. This decreases their profit margins. The consequence is that a specific firm within an emissions trading system has a lower market value than a comparable firm outside the system. With the April 2006 carbon price drop, carbon leakage becomes less of a problem for firms within an emissions trading system. The share prices of these firms will then increase. As a result, the first hypothesis H.1 is that:

Market values of firms with carbon leakage increase. Increases are larger for dirtier firms, i.e. with a higher carbon-intensity of production, than for cleaner firms. (H.1)

Hence, if firms can pass through less than 100% of their carbon-related costs, a drop in the carbon price increases the market value of such firms.

However, if firms can pass on at least 100%, i.e. they do not suffer from carbon leakage, the carbon price drop decreases product revenues, profits and thus the market value of firms.³ Indeed, Oberndorfer (2009) finds such positive share price to carbon price relationship for European power firms.⁴ The impact for dirty or clean firms is the opposite here. The carbon cost margin, i.e. the carbon price times the emissions per unit of production, is higher for firms with a dirtier production. With a lower carbon price the dirtier firms will thus face a larger product price fall, which lowers their profits and thus their share prices. As a result, the second hypothesis H.2 is that:

Market values of firms without carbon leakage decrease. Decreases are larger for dirtier firms than for cleaner firms. (H.2)

3.2 Exposure and borrowing effects

Firms in the EU ETS are allocated allowances and are exposed to carbon price developments. This impacts their profitability and, hence, share prices. Firms differ in being long or short on allowances (Anderson and Di Maria, 2011). With the April 2006 carbon price drop, firms that were short on allowances on an annual basis should face a lower cost burden every year. The hypothesis is that investors see the accumulation of these lowered cost burdens into an increase in the market value of the firm. The third hypothesis is thus as follows:

Market values increase the more firms are short on allowances. Market values decrease the more firms are long on allowances. (H.3)

However, in the short term the price drop decreases the value of allowances held in stock. This has a negative effect on the market value of the firm. One of the main features of the EU ETS Directives (2003/87/EC and 2009/29/EC) that allows firms to manage short term impacts is called ‘borrowing’. In the EU ETS firms receive their next year’s allocation of allowances prior to the compliance date for

³ This relationship holds in case of grandfathered allowances. In contrast, with auctioning the effect on market value is neutral since the allowance costs are then not only an opportunity costs but an out-of-pocket expense as well. There is literature that shows that firms make a profit when passing through these carbon related costs (e.g. Ehrhart et al., 2008) and studies that cannot confirm this (e.g. Gulli, 2008).

⁴ For Spanish firms a negative relationship was found, for which he mentions the cost pass-through restrictions on the electricity price as the most likely cause. It is indeed shown by Sijm et al. (2006) that differences in EU Member States’ market liberalization, for example the lifting of price restrictions, lead to differences in the estimated pass-through of carbon costs.

their current year's emissions. This allows firms to 'borrow' these allowances to cover for their current year's emissions. With a stock of allowances double the annual amount allocated, firms that are short on an annual basis can hereby postpone the abatement of their pollution. But in case firms foresaw the carbon price drop they would have gained most by *also* selling any of their remaining allocation holdings. Such a strategy is thus a signal of market insight. Firms with a lower net stock position should thus have a higher market value. The fourth hypothesis is then as follows:

Market values increase the more firms decreased their net stock holdings by borrowing and selling allowances. (H.4)

3.3 Trade effects

If rational expectations are assumed, firms should trade for any discrepancies between allocations and emissions. However, firms do not only trade to eliminate mismatches between allocations and emissions, they may also actively bet on carbon market developments. Active traders might know more about the workings of the market and thus have an information advantage. Investors might therefore positively value firms that are active at trading allowances, irrespective of whether they are buying or selling. The last hypothesis is thus as follows:

Market values increase the larger the firms' shares in the allowance trade. (H.5)

4. Methodology

4.1 Abnormal share returns

Since investors take into account the cost of regulation in their valuation of firms, they are supposed to discount the developments from the EU ETS as well. There is some research on the market valuation effects from market-based environmental regulations (e.g. Burtraw et al, 2002), increasingly also from the EU ETS. Most of these studies focus on the company valuation effects arising from the EU carbon price and/or in combination with energy input and output prices (e.g. Oberndorfer, 2009). A number of studies focus on the longer-term value effects of the EU ETS through the "carbon premium". For example, Oestreich and Tsiakas (2012) define this premium to be the (positive or negative) share price return differences of dirty firms compared to those of clean firms. They show that the carbon premium is positively related with larger allowance allocations. Since, especially in the first years of the EU ETS, allocations cover most of firms' emissions, this implies that investors place a higher valuation on dirtier firms. However, when focusing on energy companies in the EU, Koch and Bassen (2013) find the opposite, namely that dirtier firms have higher cost of capital due to carbon related risks and thus a lower equity value.

In order to estimate the market valuation effect specifically around the EU ETS price shock as initiated by the emissions disclosures, we use an event study instead. This approach was introduced by Fama et al. (1969) initially for corporate finance purposes, but has also been applied within the field of regulatory economics. For the latter field Schwert (1981) was one of the first to evaluate the market value impact of a regulatory change. With this methodology the aim is to explore the price impact of new information as announced to the public, as done in Bushnell et al. (2011). Previous event studies on the EU ETS have analyzed the announcement effects of national allocation plans (Mansanet-Bataller and Pardo, 2007), and the efficiency of the futures market that operates under the EU ETS (Miclăuș et al., 2008).

The event study methodology implicitly assumes that the market is efficient: all information that is available and impacts the future profits of firms is discounted into share prices. As a result, if the April 2006 event is significant for a firm it should be possible to extract from the share price the idiosyncratic or firm-specific returns associated with the event. Subsequently, these so-called

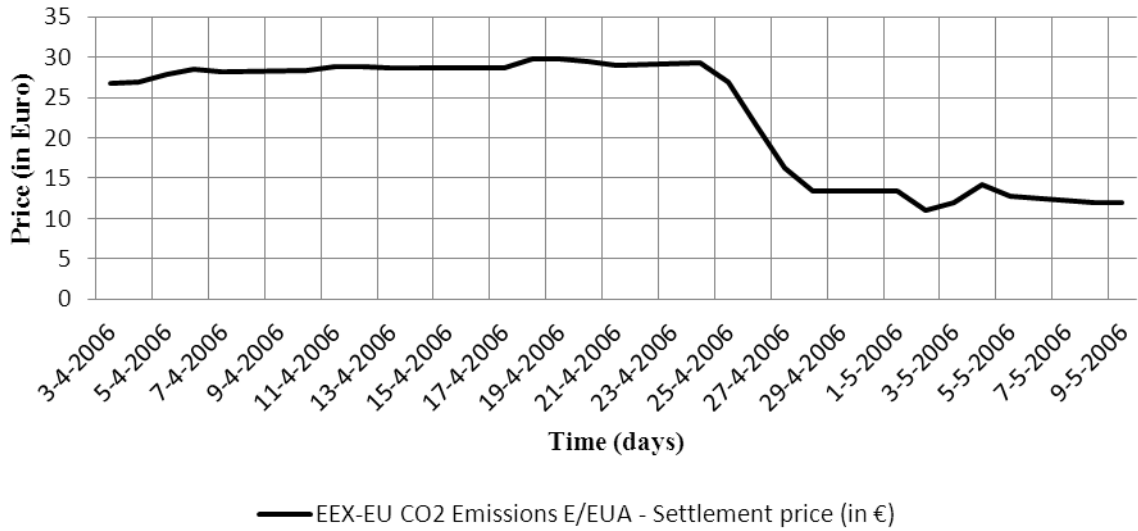
“abnormal share returns” can be analyzed by relating them to firm characteristics: in this study the abnormal returns will be related with the firms’ allocations, emissions, allowance purchases and sales, revenues, and industry categories.

For obtaining the shares and market returns, the Return Index variable (RI) was used from Datastream.⁵ With RI the returns $r_{i,t}$ can be calculated by first differencing the natural logarithms of RI :

$$r_{i,t} \equiv \log(1 + RI_{i,t}) = \ln(RI_{i,t+1} / RI_{i,t}) = \ln(RI_{i,t+1}) - \ln(RI_{i,t}) \quad (1)$$

where i stands for the company $i = 1, \dots, N$ and $i = m$ denotes the market index. These market portfolio returns $r_{m,t}$ are proxied by the RI of the Morgan Stanley Capital International (MSCI) European Union equity market index. The subscript t stands for the trading day.

Figure 2: EU Allowance Unit settlement price around the 25th of April, 2006 (in €)



As Figure 2 shows, the start of the event window is to be pinpointed at the 24th as it is the last day the price moved upwards. And since the price fall took off from the 25th we consider it the day of the event, i.e. for which $t = 0$.⁶ The inclusion of the 24th, i.e. for which $t = -1$, allows for the effects of prior information on the share prices. The event window should not encompass too many days as it may affect the degree of bias of the statistical analysis, but with too few days the impact of the event may not be captured (e.g. Binder, 1998). We therefore devise three event windows: one with the 26th of April included ($t_1 = \{-1, 1\}$) one with the 27th ($t_2 = \{-1, 2\}$), and one with the 28th ($t_3 = \{-1, 3\}$).⁷ One of our robustness tests in Section 5.7 is the impact of including an extra trading day.

In order to estimate the “abnormal” part of the returns as brought about by the event a business-as-usual estimate is needed. This estimate will be determined by running, for each firm, an OLS regression:

$$r_{i,t} = \alpha_i + \beta_i r_{m,t} + u_{i,t} \quad (2)$$

⁵ In the calculation of the Return Index, dividends or share splits are corrected for.

⁶ The disclosure of emissions by EU Member States did not take place on the same day. The shock can thus be more pronounced for firms from the countries that were first at disclosing their national demand for allowances. This differential effect has not been taken into account in this study.

⁷ Bushnell et al. (2011) take the 26th until the 28th of April as the event window, rather than the 25th until the 28th. They stated that there had been little information leaked into the market and that, otherwise, the carbon price would have responded to that. However, as Figure 2 shows, the carbon price fall had already started between the 24th and 25th.

These OLS regressions are run in a sufficiently large time period *before* the event, the so-called estimation window.⁸ For this estimation window, a 60-day period before the event is used – where 30 days are considered to be minimal for asymptotic purposes (Campbell et al., 1997).⁹ The next step is to plug the *estimation* window intercepts ($\hat{\alpha}_i$) and beta's ($\hat{\beta}_i$), and the realized firm ($r_{i,t}$) and market returns ($r_{m,t}$) from the *event* window into equation (3) to get:

$$r_{i,t} = \hat{\alpha}_i + \hat{\beta}_i r_{m,t} + \varepsilon_{i,t} \quad (3)$$

The resulting error term $\varepsilon_{i,t}$ represents the abnormal returns ($AR_{i,t}$) as caused by the event. Under Ordinary Least Squares (OLS) this term is assumed to have an expected value of zero. From a cumulative perspective these returns should thus revolve around a fixed level. Only if the returns are *significantly* affected will a new level be reached and maintained. It is therefore standard to aggregate the abnormal returns over the event window in order to see whether such an effect has been significant. For example, for t_1 these cumulative abnormal returns (CAR) can be calculated by summing $AR_{i,t}$ from $t = -1$ to $t = 1$.

4.2 Carbon leakage and carbon intensity effects

As discussed above, with the carbon price drop the firms' share prices are expected to increase *with* carbon leakage and decline *without* carbon leakage. For the carbon leakage estimate we draw on three Commission decisions (European Commission, 2010; 2011; 2012). These Commission decisions added several product categories to the tentative 'carbon leakage' list as initiated previously by Commission decision 2009/10251/EC.¹⁰ These product categories are provided in NACE codes. Since the industry classifications of EU ETS sectors are already based on NACE codes, this fits with the analysis. A dummy variable $carbleak_i$ is defined which equals 1 if a firm's NACE code is equivalent to one from the three lists as provided in the Commission Decisions.

The second factor, the carbon intensity of production (called: $carbintens_i$), is estimated by taking the 2005 emissions and dividing them by the 2005 revenues.^{11,12} The effect of carbon intensity on share prices depends on whether a firm suffers from carbon leakage. We take care of this interaction via a variable $carbileak_i$, which is the product of $carbintens_i$ and $carbleak_i$. Hypothesis H.1 suggests that with carbon leakage, the share prices of dirtier firms increase more than those of cleaner firms. Hypothesis H.1 will then be accepted if $carbleak_i$ as well as $carbileak_i$ are positively related to CAR_i . Hypothesis H.2 suggests that without carbon leakage, the share prices of dirtier firms decrease more than those of cleaner firms. To accept Hypothesis H.2 the opposite should thus hold.

⁸ The effects of choosing the estimation window *after* the event is one of the robustness checks we carried out in Section 5.7.

⁹ To prevent that market prices or events from the estimation window affect the event window, a time period of 5 days in between the estimation and event window is allowed for. With 60 days being the length of the estimation window, the estimation window would correspond to January 20th to April 13th, 2006.

¹⁰ For Phase III (2012-2020) firms whose production falls under this list of carbon leakage NACE codes receive a 100% free allocation.

¹¹ Although the revenues pertain to the entire firm, not all of its emissions may be covered by the EU ETS. For example, firms that only have one installation in the EU and the rest abroad may thus seem to have clean production. The Orbis database, however, does not provide the percentage of revenues which are attributable to these installation(s). Yet to the extent of the exposure to the EU ETS, such firms indeed have 'clean' output and thus low pollution costs as their lower exposure enables them to switch production to the non-EU ETS installations.

¹² For some firms, Orbis did not provide data on revenues while Datastream was able to. For several of these firms, Datastream provided data on a quarterly/monthly rather than an annual basis.

4.3 Exposure and borrowing effects

Regarding the value effects associated with allocations and emissions two effects are important: 1) an exposure valuation: what are the allocations minus the emissions amounts to come, and 2) a stock valuation: what is the value of the allowances which firms currently have in stock.¹³ As regards the first valuation effect, it is expected that an investor will see these annual shortfalls or surpluses in relative terms. With data on allocations and verified emissions one thus only needs to take the difference and divide it by the allocations or emissions. But for a part of the EU ETS database, the Community Independent Transaction Log (CITL), it could not be discerned whether allocations belonged to the first or second tranches. The sum of the two allocations was therefore taken, resulting in the following exposure variable:

$$\text{exp} = \frac{\text{allocation}_{i,2005} + \text{allocation}_{i,2006} - 2 * \text{emissions}_{i,2005}}{\text{allocation}_{i,2005} + \text{allocation}_{i,2006}} * 100\% \quad (4)$$

where $\text{emissions}_{i,2005}$ are multiplied by two given the two allocation tranches.^{14,15} Hypothesis H.3 suggests that market values increase (decrease) the more firms are short (long) on allowances. Hypothesis H.3 will then be accepted if exp_i is negatively related to CAR_i .

For the second effect, the stock valuation, we devised a net holding estimate which takes into account 1) the possibility for firms to borrow from their second allocation tranche, and 2) the firms' net allowances sales – since, at higher pre-event carbon prices, it would have been profitable if firms had also sold their second allocation tranche. For the event study, the reference date for the net holdings is set at the 30th of April, 2006, when allowances ought to have been handed in to the national authorities. The net holding of an installation at April 30th is then defined as:

$$\text{borrow}_i = \frac{\text{emissions}_{i,2005} + \sum_{2005}^{\text{Apr } 2006} \text{sales}_i - \sum_{2005}^{\text{Apr } 2006} \text{purchases}_i}{\text{allocation}_{i,2005} + \text{allocation}_{i,2006}} * 100\% \quad (5)$$

Hypothesis H.4 suggests that market values increase the more firms decreased their stock holdings. Hence, for Hypothesis H.4 to be accepted borrow_i needs to be positively related to CAR_i .

4.4 Trade effects

Investors may value firms that are active at trading allowances, irrespective of whether they are buying or selling. The estimate we hereby adopted is the intensity of trade (called: tradeintens_i). This is defined as the sum of a firm's purchases and sales divided by the sum of the EU ETS total of

¹³ This short to long-term dichotomy is a parallel to Johnston et al. (2008). They test the market valuations of whether firms hold surpluses of allowances, to: 1) reduce future cash outflows associated with emissions, or 2) to allow the management of a firm to defer investments in abatement capital.

¹⁴ A second issue is that not all allowance surrenders took place before the 30th of April – as required by EU Directive 2003/EC/87. The Dutch Emissions Authority informed us that the EU Directive 2003/87 allows EU Member States some flexibility when to impose a penalty for such non-compliance (as Article 16 par. 3 of the EU Directive 2003/87 could conflict with Article 12 par. 3).

¹⁵ As the National Allocation Plans predetermined most of the allocations for Phase I it should pose less of a problem to assume that emissions for 2006 equal those of 2005.

purchases and sales, again at April 30th.¹⁶ In addition, a dummy variable *notrade_i* is defined which equals 1 for firms which had nor purchases nor sales, and zero otherwise.

Hypothesis H.5 suggests that market values increase the larger the firms' shares in the allowance trade. Hence, for Hypothesis H.5 to be accepted *tradeintens_i* needs to be positively related to *CAR_i*.

5. Results

5.1 Firm and industry selection criteria

Firms were selected if they took part in the EU ETS by either having received allocations, by having traded allowances, or both. As to those receiving allocations we identified the operators of the installations as provided in the National Allocation Plans (NAP) and Community Independent Transaction Log (CITL) via Orbis. For 10.356 of the 10.651 installations in the EU ETS, 6.161 operators were identified. Next to the operators of installations, there were 511 business units which only traded in allowances. Both these groups of firms were, if possible, matched with their Global Ultimate Owners (GUO) and checked whether they were listed on a stock exchange. Via the International Security Identification Numbers (ISIN) share price data could be retrieved for 470 stock exchange quoted firms. Due to data unavailability in the EU ETS transactions database or in Datastream, this number decreased to 393 firms.

In order to classify firms into ETS sectors, from Orbis we gathered the firms' NACE Rev 2. core codes and the text descriptions linked to these codes. Given these descriptions the firms were categorized into the following ETS sectors: 1) Power & Heat, 2) Iron, Steel & Coke, 3) Cement & Lime, 4) Refineries, 5) Pulp & Paper, 6) Glass, 7) Ceramics, Bricks & Tiles, 8) Others.¹⁷

5.2 Cumulative abnormal returns

The share prices, which determined the abnormal returns, are themselves established at the end of each trading day. The share prices should thus reflect the carbon price changes both on $t = 0$ for the initial decline and on $t = 1$ for the acceleration of the fall (cf. Figure 2).

¹⁶ It is worth mentioning that this trade data, i.e. from the CITL registry transactions, is published five years after an EU ETS calendar year. Investors thus did not have it at their disposal during or before the event. In this analysis it thus functions as a trade proxy. Investors should have obtained their allowance trading estimates via other information sources.

¹⁷ This categorization is applied in more studies, among others in Ellerman and Joskow (2008).

Figure 3: The full sample average abnormal returns within event window $t = \{-2,3\}$

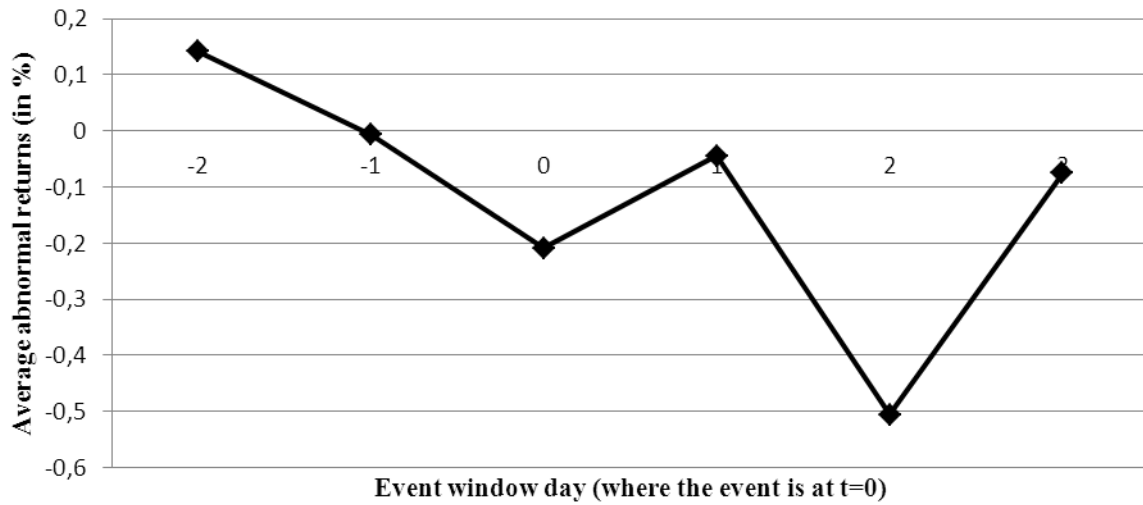


Figure 3 shows the path of the full sample average abnormal returns (not the *CARs*) for the 393 firms over an event window of $t = \{-2,3\}$. This event window illustrates that before and until the event day $t = 0$, the abnormal returns gravitated to the negative. The initial and positive response to the news came at $t = 1$, suggesting it took some time before investors realized the information had an impact on the firms' valuations. The market re-evaluated this shock (downwards) at $t = 2$. And it took a further day for the *CARs* to tend back to zero, indicating that the impact was not substantial overall. We thus expect the event window $t_1 = \{-1,1\}$ to be informative as it includes the main initial response to the news. Other event windows we consider are $t_2 = \{-1,2\}$ and $t_3 = \{-1,3\}$ which will provide insights into the share price corrections the days after.

Table I: Descriptive statistics on the CARs and on their significance

ETS sectors: 1) Power & Heat 2) Iron, Steel & Coke 3) Cement & Lime 4) Refineries 5) Pulp & Paper 6) Glass 7) Ceramics, Bricks & Tiles 8) U/I Others. The sector classifications are performed through NACE Rev 2. core codes. *** / ** / *: 99% / 95% / 90% significance.

CAR(-1,1)	Full sample N = 393	Sector 1 N = 25	Sector 2 N = 34	Sector 3 N = 13	Sector 4 N = 67	Sector 5 N = 34	Sector 6 N = 5	Sector 7 N = 4	Sector 8 N = 211
Mean	-0,003	-0,009	-0,003	0,011	-0,005	-0,006	-0,003	0,019	-0,002
Std. dev.	0,029	0,026	0,040	0,031	0,030	0,026	0,020	0,024	0,028
Median	-0,002	-0,006	-0,001	0,006	-0,005	-0,003	-0,007	0,019	-0,002
Minimum	-0,131	-0,070	-0,131	-0,021	-0,084	-0,070	-0,023	-0,011	-0,116
Maximum	0,119	0,048	0,082	0,090	0,099	0,063	0,030	0,048	0,119
T-test	-1,71*	-1,74*	-0,45	1,28	-1,3	-1,41	-0,31	1,54	-0,82
SCAR test	-1,68*	-2,61***	-0,61	2,58***	-2,61***	-2,34**	0,43	2,88***	0,16

CAR(-1,2)	Full sample N = 393	Sector 1 N = 25	Sector 2 N = 34	Sector 3 N = 13	Sector 4 N = 67	Sector 5 N = 34	Sector 6 N = 5	Sector 7 N = 4	Sector 8 N = 211
Mean	-0,008	-0,020	-0,023	0,004	-0,012	-0,012	0,005	0,016	-0,003
Std. dev.	0,041	0,028	0,043	0,030	0,037	0,029	0,033	0,036	0,045
Median	-0,007	-0,013	-0,019	-0,0005	-0,007	-0,014	-0,010	0,020	-0,003
Minimum	-0,210	-0,086	-0,110	-0,030	-0,111	-0,072	-0,028	-0,031	-0,210
Maximum	0,364	0,024	0,102	0,087	0,096	0,070	0,055	0,055	0,364
T-test	-3,63***	-3,54***	-3,17***	0,46	-2,55**	-2,44**	0,33	0,9	-0,95
SCAR test	-6,97***	-6,07***	-6,04***	0,88	-5,2***	-4,37***	1,01	2,56**	-1,04

CAR(-1,3)	Full sample N = 393	Sector 1 N = 25	Sector 2 N = 34	Sector 3 N = 13	Sector 4 N = 67	Sector 5 N = 34	Sector 6 N = 5	Sector 7 N = 4	Sector 8 N = 211
Mean	-0,008	-0,017	-0,017	0,003	-0,015	-0,011	-0,003	0,016	-0,004
Std. dev.	0,050	0,034	0,057	0,035	0,043	0,044	0,049	0,028	0,054
Median	-0,009	-0,012	-0,020	0,005	-0,012	-0,013	-0,027	0,016	-0,005
Minimum	-0,252	-0,102	-0,113	-0,034	-0,124	-0,090	-0,051	-0,017	-0,252
Maximum	0,439	0,030	0,131	0,088	0,099	0,123	0,052	0,050	0,439
T-test	-3,3***	-2,56**	-1,78*	0,32	-2,87***	-1,44	-0,13	1,19	-1,2
SCAR test	-7,85***	-5,21***	-5,07***	0,55	-7,05***	-3,89***	0,96	2,58***	-2**

Table I shows the descriptive statistics for the cumulative abnormal returns (CAR) for the three event windows $t_1 = \{-1,1\}$, $t_2 = \{-1,2\}$, and $t_3 = \{-1,3\}$.¹⁸ From t_1 to t_2 the average firm saw a decline in the mean of its CAR, but there was no average change from t_2 to t_3 .

Although the CARs seem small, the total value effect is substantial. Multiplying all listed firms' CARs with their average equity market values in April, 2006, yields a net value effect of € -54 billion

¹⁸ The CAR statistics provided are in basis points rather than percentages.

for the window t_2 .¹⁹ To put these figures into perspective, we can estimate the change in the opportunity costs of holding allowances by taking the carbon price drop over t_2 (€ 13,14) and multiplying it by the sum of the firms' two remaining allocations for Phase I (2005-2007).²⁰ We find that these opportunity costs account for 1,22% of the firms' *total* April 2006 average equity market values, and 55,5% of the *change* in the April 2006 average equity market value as caused by the carbon price drop.

For the significance of the *CARs* two types of test statistics are provided: the t-test and the standardized *CAR* (or: *SCAR*) test.²¹ The *SCAR* test weighs the *CARs* with the standard error of the estimation regression (cf. Section 4.1, formula 2). The corresponding p-values in Table I show that the (S)*CARs*, from a statistical perspective, are significantly different from zero.

If we consider t_1 , the event window with the initial response to the news, the *SCAR* test statistics point to significance of returns for five ETS sectors. However, the mean *CAR* from the full sample is only significant at the 90% confidence level. As they are more significant for t_2 and t_3 , this lends further support for the analysis to include the latter two days in the event windows. In t_2 and t_3 four of the sectors had significant negative returns (sectors 1, 2, 4, and 5), and one had small negative returns (sector 8).²² Hence, also from a sector perspective it is clear that the returns were negative in general.

5.3 Carbon leakage and carbon intensity effects

The first section from Table II shows the full sample statistics on the effects from carbon leakage and the carbon intensity of production.²³ The variable *carbintens*, or the tonnes of CO₂ a firm emits per unit of revenues, has an average of 0,0004 and a median of 0,00003. The associated positive skewness value of 6,55 indicates that there are few firms emitting many emissions per unit of revenues and a lot of firms with few emissions per unit of revenues. The mean of *carbleak* (55%) shows that the majority of firms is prone to carbon leakage.

¹⁹ The net effect consists of firms with a negative event and with a positive event effect. The negative effect amounts to € - 109,5 billion and the positive effect to € 55.6 billion.

²⁰ We assume that firms have already made use (most) of their first allocations to cover for their 2005 emissions. The opportunity costs of holding allowances will then relate to the already received allocation over 2006 but also the allocation for 2007, from which firms are able to borrow for their 2006 emissions.

²¹ The latter test can be found in Campbell et al. (1997, section 4.4).

²² We leave sectors 6 and 7 out of the discussion due to the small number of observations.

²³ Table II and Table III below provide these statistics on differing amounts of firms. Of the total amount of 393 firms, there were 377 firms which received a positive allocation: *exp* and *borrow* could not be determined for the excluded 16 firms. A further 11 firms had only inter-firm transactions, i.e. they had neither allocated nor verified allowances.

Table II: Full sample descriptive statistics on the product market, exposure and borrowing, and allowance trading

carbintens is calculated by taking the firm's 2005 emissions and dividing these by its 2005 revenues. *carbleak* equals 1 if a firm's NACE industry code matches one from the carbon leakage lists as provided in Commission Decisions 2009/10251/EC, 2011/8017/EC and 2012/498/EC. *carbileak* is the product of a firm's *carbintens* with its *carbleak* values. *exp* is calculated by taking the difference between the sum of a firm's 2005 and 2006 allocations and two times its 2005 emissions, and dividing it by the sum of its 2005 and 2006 allocations. *borrow* is calculated by taking a firm's 2005 emissions plus its cumulative net sales of allowances up to April 2006, and dividing it by the sum of its 2005 and 2006 allocations. *tradeintens* is calculated by taking the sum of a firm's cumulative purchases and cumulative sales of allowances up to the 30th of April, 2006, and dividing it by the full sample's cumulative purchases and cumulative sales of allowances up to the 30th of April, 2006. *notrade* equals 1 for firms with a *tradeintens* equaling zero.

Full sample	Mean	Std. dev.	Median	Min.	Max.	Skew.	N
<i>carbintens</i>	0,0004	0,001	0,00003	0	0,01	6,55	366
<i>carbleak</i>	0,55	0,5	1	0	1	-0,21	393
<i>carbileak</i>	0,0002	0,0006	0	0	0,0068	6,65	366
<i>exp</i>	10,9	54,86	12,52	-928,57	100	-13,44	377
<i>borrow</i>	-78,11	2.285,11	47,48	-44.237,1	232,36	-19,3	377
<i>tradeintens</i>	0,25	1,03	0	0	9,53	5,58	393
<i>notrade</i>	0,55	0,5	1	0	1	-0,19	393

Table III: Sector level descriptive statistics on the product market, exposure and borrowing, and allowance trading

Under (A) the full sample or sector averages of the variables can be found. These are determined by taking the averages within the full sample and within each sector. Under (B) the full sample or sector ratios of *carbintens*, *exp*, *borrow*, and *tradeintens* can be found. These are calculated as follows: for *carbintens*, by dividing the full sample or sector's total emissions by the full sample or sector's total revenues; for *exp*, by taking the sum of the full sample or sector's 2005 and 2006 allocations, subtracting its full sample or sector's 2005 emissions, and dividing this difference by the sum of the full sample's or sector's 2005 and 2006 allocations; for *borrow*, by taking the full sample's or sector's 2005 emissions, subtracting its full sample's or sector's cumulative net sales of allowance up to the 30th of April 2006, and dividing this difference by the sum of the full sample's or sector's 2005 and 2006 allocations; for *tradeintens*, by taking the sum of the full sample's or sector's cumulative purchases and cumulative sales of allowances up to the 30th of April, 2006, and dividing it by the full sample's cumulative purchases and cumulative sales of allowances up to the 30th of April. ETS sectors: 1) Power & Heat 2) Iron, Steel & Coke 3) Cement & Lime 4) Refineries 5) Pulp & Paper 6) Glass 7) Ceramics, Bricks & Tiles 8) U/I Others.

		Full sample	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Sector 7	Sector 8
<i>carbintens</i>		N = 366	N = 23	N = 33	N = 12	N = 67	N = 32	N = 5	N = 4	N = 190
	A	0,0004	0,0026	0,0005	0,0015	0,0002	0,0004	0,0005	0,0005	0,0001
	B	0,0001	0,0016	0,0003	0,0009	3,6E-05	0,0001	0,0002	4,3E-05	2,8E-05
<i>carbileak</i>	A	0,0002	5,4E-08	0,0002	0,0014	0,0002	0,0004	0,0005	0,0005	2,4E-05
<i>carbleak</i>		N = 393	N = 25	N = 34	N = 13	N = 67	N = 34	N = 5	N = 4	N = 211
	A	0,55	0,04	0,91	0,77	0,84	0,91	1,00	1,00	0,36
<i>exp</i>		N = 393	N = 23	N = 33	N = 13	N = 67	N = 33	N = 5	N = 4	N = 199
	A	10,9	-1,00	10,08	15,22	14,51	24,00	11,71	13,7	8,68
	B	-0,99	-13,92	22,00	9,16	13,31	24,00	10,53	21,61	9,53
<i>borrow</i>		N = 393	N = 23	N = 33	N = 13	N = 67	N = 33	N = 5	N = 4	N = 199
	A	-78,11	65,4	48,74	45,54	49,18	51,24	29,65	50,05	-193,4
	B	48,37	48,74	54,91	46,13	49,68	50,35	-2,53	49,59	45,04
<i>tradeintens</i>		N = 377	N = 23	N = 33	N = 13	N = 67	N = 33	N = 5	N = 4	N = 199
	A	0,25	1,64	0,19	0,26	0,07	0,02	0,58	0,001	0,19
	B	100	41,08	6,59	3,34	4,36	0,80	2,89	0,01	40,93
<i>notrade</i>	A	0,55	0,2	0,56	0,38	0,54	0,47	0,2	0,5	0,62

The first section of Table III provides for *carbintens* a full sample average, sector averages and a 'sector ratio'. The latter is calculated by considering each sector as being one 'firm'. Hereby the allocations, surrenders, allowance purchases and sales are summed up per sector. Both the sector average (A) and the sector ratio (B) indicate that sector 1 (Power & Heat) and less so sector 3 (Cement & Lime) have most tonnes of CO₂ per unit of revenue. Compared to the six other sectors, their production is three to twenty-six times more carbon-intensive. Sector 8 (Unidentified / Others) and sector 4 (Refineries) have the least tonnes of CO₂ per unit of revenue. It is remarkable that the carbon leakage rates differ so much. Whereas 4% and 77% of the firms in the carbon-intensive sectors 1 and 3, respectively, are prone to carbon leakage, it is 84% and 36% for firms in the carbon-extensive sectors 4 and 8, respectively.

Furthermore, sector 1 and sector 3 have the highest level of carbon intensity, but differ with respect to carbon leakage. In accordance with Hypothesis H.1, Sector 3 with its high carbon leakage has seen

positive CARs due to the carbon price drop. And Sector 1, with no carbon leakage, has seen negative CARs, which is in accordance with Hypothesis H.2. The outcomes of sectors 4, 5, and 8 are not in line with Hypothesis H.1 or H.2 since positive CARs were to be expected, given their carbon leakage.

5.4 Exposure and borrowing effects

Table II further reports the descriptive statistics for the variables *exp* and *borrow*. It shows that most firms were long on allowances; see the positive average and median values of *exp*.

The variable *borrow* is the ratio of the stock of allowances on the 30th of April 2006 divided by the allocations of 2005 and 2006. The mean of -78% shows that the average firm used up and sold less allowances than it has purchased. However, the median of 47,5% shows that the median firm has used up 95% of its first term allocation and banked the remainder plus the second allocation. This implies that a few firms skew the borrow variable towards a large negative mean, i.e. most firms were long in allowances.

That these surpluses were subsequently not sold off is an indication that many of them did not foresee the carbon price drop. On the other hand, the picture from borrow may be distorted. Our data only contains transactions from the spot market but not from the derivatives market. Firms which purchased allowances on the spot market and sold them (at higher prices) through forwards and futures thus come out as not having foreseen the carbon price drop, while they actually may have profited from it via the derivatives market. This may be the case for three firms (Barclays PLC, AB Electrolux, and Severn Trent PLC) which had highly negative borrow values.²⁴

The sector perspective on *exp* and *borrow* is provided in the second section of Table III. Provided are the full sample averages, sector averages and a sector ratio. For most sectors the averages differ from their sector ratio, but the signs do not. The result remains that all except sector 1 (Power & Heat) are long on allowances. Interestingly, the full sample average of 11% differs from the full sample sector ratio for the EU ETS of -1%. It implies that on average firms are long but on the whole the EU ETS is short. This number is close to the range of the EU ETS allocation estimations from Ellerman and Buchner (2008) and Anderson and Di Maria (2011). These were in the order of +0,6% and -0,5%, respectively. Hence, although the number is small, in aggregate the listed firms faced pressure to reduce their pollution.

The sector values for borrow are in accordance with those of Table II as values were in the 45% to 50% range. This again indicates that on average less than one allocation tranche had been used. Only sectors 1, 5, and 7 have borrowed from their second allocation tranches as their borrow rates were in the range of 50 - 100%. For sector 1 it is to be expected to borrow given its shortfall in allowances. Sector 5 (Pulp & Paper), however, is long in allowances but the data show that pulp and paper firms used 51% of their two allocation tranches, either via covering its emissions or via net sales.

5.5 Trade effects

The last statistics in Table II are on the allowance trade. As the zero median of *tradeintens* indicates, most firms did not trade in allowances. The mean of *notrade* indicates this was the case for 55% of firms. Furthermore, the average firm's share of total EU ETS purchases and sales was 0,25%. As the standard deviation is 1,03 and the maximum value is 10%, a few firms conducted most of the trade in allowances.

²⁴ Relative to their purchases and sales, their allocations and surrenders of allowances were very small. This turned their *borrow* values to the negative. The minimum value is -44.237%. The outlier statistics did not detect these three firms as outliers (cf. footnote 27), so they were included in the analysis.

The differences in trading among the industry sectors is provided in the last section of Table III. The sector ratios of *tradeintens* show that most trade originates from sector 1 (Power & Heat) and 8 (Unidentified / Others) with, respectively, 41,1% and 40,9% of total allowance trade among the listed firms. The sector averages, though, indicate that the average firm in sectors 2, 3, and 6 traded about as much or even more than the average firm within sector 8. Sectors 4, 5, and 7 were the least active.

5.6 Cross-sectional regression

Table IV shows that correlations among variables are low, suggesting that multicollinearity will be a minor issue.²⁵ Furthermore, most of the correlations are in line with expectations. For instance, firms susceptible to carbon leakage have a lower trade intensity (correlation among *carbleak* and *tradeintens* equals -0,13) due to their long position in allowances (correlation among *carbleak* and *exp* equals 0,07).

Table IV: Correlation matrix of the variables used in the regressions

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) <i>CAR(-1,1)</i>	1									
(2) <i>CAR(-1,2)</i>	0,78	1								
(3) <i>CAR(-1,3)</i>	0,74	0,9	1							
(4) <i>carbintens</i>	-0,07	-0,13	-0,08	1						
(5) <i>carbleak</i>	0,02	-0,03	-0,01	-0,06	1					
(6) <i>carbileak</i>	-0,03	-0,09	-0,12	0,47	0,25	1				
(7) <i>exp</i>	0,03	0,02	0,02	-0,04	0,07	0,004	1			
(8) <i>borrow</i>	0,005	-0,01	-0,02	0,02	0,06	0,02	0,02	1		
(9) <i>notrade</i>	-0,08	-0,05	-0,06	-0,13	0,01	-0,07	-0,003	0,06	1	
(10) <i>tradeintens</i>	-0,06	-0,06	-0,04	0,23	-0,13	0,04	-0,05	-0,38	-0,27	1

In the Ordinary Least Squares (OLS) regressions the statistics point to non-normal distribution of the residuals.²⁶ Normality of residuals, though, is not a sufficient condition for obtaining consistent estimates. In order to test whether the assumptions of the regression models are correct, Long and Trivedi (1992) suggests applying two types of specification tests: the robust LM Ramsey's RESET test and the Information Matrix (IM) test as in Cameron and Trivedi (1990).²⁷ If these tests are passed the "interpretation of OLS estimates and application of standard statistical tests are justified" (Long and Trivedi, 1992).

There are five hypotheses to test over three event windows. We group the variables in four blocks related to these hypotheses. Then we take up all significant variables in a subsequent regression.

²⁵ In the regressions multicollinearity is checked for by means of the variation inflation factors.

²⁶ Three measures to detect outliers were considered, as suggested in Baum (2006, section 5.2.10): the deviation of the residual, and the leverage and influence of the observation. Over the three event windows the observations of Nature Group PLC and Providence Resources PLC were consistently detected by these measures, and were therefore left out of the analysis.

²⁷ The IM test focuses on the second (homoskedasticity), third (skewness), and fourth (kurtosis) moments.

Table V: OLS regressions on the CARs from event windows t1, t2, and t3

	Event window t ₁					Event window t ₂					Event window t ₃				
	H.1-H.2	H.3	H.4	H.5	H.1-H.5	H.1-H.2	H.3	H.4	H.5	H.1-H.5	H.1-H.2	H.3	H.4	H.5	H.1-H.5
<i>carbintens</i>	-1,649** (0,043)				-1,531** (0,022)	-3,782*** (0,0004)				-4,086** (0,017)	-1,339* (0,067)				-3,107 (0,251)
<i>carbleak</i>	-0,0003 (0,916)					-0,003 (0,187)					0,001 (0,711)				
<i>carbileak</i>	0,005 (0,997)					-1,831 (0,626)					-7,767 (0,161)				
<i>tradeintens</i>		-0,002* (0,08)			-0,0005 (0,52)		-0,003** (0,042)			-0,0003 (0,682)		-0,003* (0,082)			-0,0005 (0,761)
<i>notrade</i>		-0,006 (0,144)					-0,005 (0,377)					-0,008 (0,328)			
<i>exp</i>			1,64E-05* (0,099)		1,29E-05** (0,036)			1,56E-05 (0,128)					1,27E-05 (0,348)		
<i>borrow</i>				5,56E-08* (0,066)	-2,6E-08 (0,832)				-1,3E-07 (0,211)					-4,5E-07*** (0,001)	-5,2E-07 (0,123)
constant	-0,002 (0,421)	0,001 (0,72)	-0,002** (0,044)	-0,002* (0,051)	-0,002** (0,049)	-0,004 (0,164)	-0,004 (0,601)	-0,007* (0,072)	-0,007* (0,073)	-0,006* (0,072)	-0,007** (0,022)	-0,003 (0,637)	-0,008** (0,032)	-0,008** (0,029)	-0,007** (0,014)
R ²	0,005	0,011	0,001	0,000	0,006	0,019	0,008	0,0005	0,0001	0,016	0,014	0,007	0,0002	0,0005	0,007
Adjusted R ²	-0,003	0,006	-0,002	-0,003	-0,005	0,011	0,003	-0,002	-0,003	0,011	0,006	0,002	-0,002	-0,002	-0,001
AIC	-1541,85	-1663,88	-1596,2	-1595,85	-1540,14	-1318,08	-1391,07	-1358,92	-1358,77	-1319	-1177,94	-1242,5	-1215,56	-1215,65	-1175,28
N	366	393	377	377	366	366	393	377	377	366	366	393	377	377	366
F-test	0,110	0,192	0,099	0,066	0,044	0,001	0,008	0,128	0,211	0,005	0,010	0,188	0,348	0,001	0,002
RESET	0,292	0,151	0,157	0,355	0,297	0,496	0,163	0,668	0,426	0,501	0,136	0,197	0,607	0,497	0,233
IM_total	0,071	0,144	0,109	0,102	0,781	0,806	0,430	0,714	0,720	0,955	0,803	0,610	0,693	0,717	0,998

*/**/***: 90%/95%/99% confidence level. The variables are estimated with robust clustered standard errors. The p-values are within brackets. N is the number of observations. (Adjusted) R² is the (adjusted) coefficient of determination. AIC is the Akaike Information Criterion. The null of RESET is that the conditional mean of the dependent variable is correctly and robustly specified; the null of IM-total is "a joint test of heteroskedasticity, skewness, and nonnormal kurtosis compared with the null hypothesis of homoskedasticity, symmetry, and kurtosis coefficient of 3" (Cameron and Trivedi, 2009). STATA 12 does not provide the IM test statistics after clustered robust estimations. These are computed with robust (non-clustered) standard errors.

In Table V the OLS results with robust clustered standard errors are provided for the three windows.²⁸ The two specification tests do not point towards a misspecification of the estimated model.²⁹

Over the event windows, four variables had a significant impact on the *CARs*: *carbintens*, *tradeintens*, *exp* and *borrow*. The variable of *carbintens* shows up in two of the three full model regressions, *exp* in one of them, and *borrow* and *tradeintens* in none of them. The variable *carbintens* has a negative parameter indicating that the carbon price drop has a more negative impact on share prices of dirtier firms than on those of cleaner firms. For example, for event window t_2 , if a firm would have an increase in its *carbintens* by one standard deviation, this would lead to an average *CAR* decrease of -0,41%. Relative to the *CAR* average of -0,8% for this window, this is quite substantial.

The second variable, *exp*, is only significant in t_1 . The positive estimate of *exp* indicates that the carbon price drop led to a larger share price increase for firms which were more ‘long’ or less ‘short’ on allowances. Increasing *exp* by 10% translates into an average *CAR* impact of 0,013%. Since the full sample average of event window t_1 equals -0,3% its impact is small.

The variables *tradeintens* and *borrow* come up in the separate regressions but are absent from the full model regression results. It is likely that *carbintens* and/or *exp* captured the variance from the *CARs* instead.

5.7 Robustness

The main feature which makes analyses of regulation impacts on market values problematic is that regulatory changes are generally not sudden, but often gradual and expected (see e.g. Binder, 1998). The lower the degree of ambiguity as to what the key dates in the regulatory process are (see Figure 1), the better an event study might estimate the effects. However, the information on the excess amount of allowances came as a shock to the market. This shock is clearly observable in the data, e.g. through Figures 1, 2, and 4. Moreover, in the April 21st 2006 edition of *Carbon Market Europe* of Point Carbon, one of the leading information providers on CO₂-markets, it was argued that the CO₂ price was too low (Ellerman and Buchner, 2008). The expectations before the event thus indicate a CO₂ price movement in the opposite direction.

In the estimations we used heteroskedasticity-consistent and clustered standard errors. Furthermore, we checked the regressions results with three other event windows than those presented here. The results are in line with those from the presented event windows: the carbon intensity of output is the main factor. The short term stock holdings as proxied by *borrow* are significant but have a negligible impact.

With an increasing carbon price, share price returns before the event are supposed to be higher for cleaner and lower for dirtier firms. Since business-as-usual estimates are based on pre-event data, the ‘normal’ returns may therefore be overestimated for the cleaner firms and underestimated for the dirtier firms (see e.g. Salinger, 1992). With a carbon price drop, share price reactions might then also be larger than what is to be expected. A check on such an effect is therefore to use an ex-post event estimation window for calculating *CAR* values. In the results the variables *tradeintens* and *borrow* attain a higher level of significance, and *carbintens* less so. However, the specification tests point towards a misspecification of the estimated models. It is therefore not justified to interpret the OLS estimates and t-tests.

²⁸ We use robust clustered standard errors based on the eight industry sectors. The WLS estimates are not provided here as these had a lower fit with the data. They are available upon request.

²⁹ Only at 93% confidence would the model of H.1-H.2 in event window t_1 be misspecified. But since *carbintens* is also significant in the full model regression of H.1-H.5, which is correctly and robustly specified, it will be valid to interpret its estimate.

Another hurdle affecting cross-sectional regressions is cross-sectional dependence, e.g. when abnormal returns are caused by a common event – as is the case here. Karafiath (2004) shows that this may lead to heteroskedasticity and biased and correlated error terms. He therefore proposes using both weighted least squares (WLS) and ordinary least squares (OLS) with robust (heteroskedasticity-consistent) standard errors. We performed a WLS regression using the standard errors of the estimation window regressions as weight to check our OLS results.³⁰ As these results do not differ from the OLS results we do not discuss them here.³¹

6. Discussion

A first inference one can make from Table V is that the fit of the model on the abnormal returns is weak, given the low R-squared and adjusted R-squared. Yet, this is to be expected since the carbon price effect only indirectly relates to share prices of firms. There can always be non-EU ETS related factors that play a role in determining the share price movements, such as changes in the macro-economic environment e.g. interest rates and oil price movements. And as to the EU ETS related factors, rather than the selected variables it may well be that the EU ETS impact on share prices manifests itself through other channels. For example, a firm's state of abatement technology and business strategy with regard to climate change regulation – i.e. factors which are hardly measurable. Related to that, the 2006 carbon price shock may have changed the investors' expectations on the stringency of the future EU ETS. It is likely that investors expected the carbon price drop to induce unanimity among policymakers for decreasing the EU ETS cap in future phases. Indeed, in October 2006 the European Commission announced stricter NAPs for Phase II.³² This thus might provide an explanation why the overall abnormal returns were negative, despite the fact that a lower carbon price should generally be conceived as good news for cost-effectively achieving given emission targets. At the moment of writing, the demand for EU ETS allowances is again not keeping up with its supply, resulting in a carbon price which hit a level below € 3 Euro early 2013. This may again make investors expect that policymakers will decide on a stricter EU ETS in future.

Among the variables hypothesized to have an effect, Table V indicates that the carbon-intensity of revenues is the important determinant of the abnormal returns. For the other factors the impact is limited (*exp*) or its variance is captured by *tradeintens* and/or *borrow*. We discuss them after the main determinant: the carbon-intensity of outputs.

From the regression results the variable *carbleak* was not significant, and *carbintens* is negatively related to the CARs. The fact that investors value the carbon-intensity of outputs negatively is, in a way, a sign that the EU ETS is valued as a restriction on pollution. The negative parameter of *carbintens* points towards a longer term market perception: that firms are considered more competitive with lower carbon-intensity rates as these signal towards better abatement capacities. This finding is in line with Koch and Bassen (2013) and runs counter to Oestreich and Tsiakas (2012) who concluded that investors demand a higher carbon risk premium for the (expected higher) cost of capital of dirtier firms due to their higher carbon related risks.

The insignificance of *carbleak* means that Hypotheses H.1 and H.2 are rejected. The descriptive statistics show that only sector 1 (Power & Heat) and sector 3 (Cement & Lime) provide support for Hypothesis H.1 and H.2. They had considerable carbon-intensive production, low and high levels of carbon leakage, respectively, and negative and positive CAR returns as expected. However, among the six other sectors it was the opposite: higher carbon leakage rates and more carbon-intensive production led to more negative CAR returns. There can be several reasons for these incompatible findings. For

³⁰ This approach is mentioned in e.g. Binder (1998, p. 6 and 7).

³¹ The fit of the models with the data is less than in the OLS regressions. The results are available on request.

³² In Alberola et al. (2008) this announcement is considered in their analysis of carbon price drivers.

one thing, the variable *carbleak* may not have sufficient detail. Unknown is the actual carbon pass-through rate by firms. It is further probable that this cost pass-through threshold, for which market value impacts turn positive, does not lie at/above 100% but at lower rates. Further research is necessary to find this out.

The next variable, *exp*, was found to be positively related with the *CARs*. This is in contrast with Hypothesis H.3: that market values increase (decrease) the more firms are short (long) on allowances. This positive *exp*-to-*CARs* relationship is in line with Abrell et al. (2011) that over-allocated firms were more profitable, the latter of which should correspond to higher share prices.

The impact on *CARs* from trade, or *tradeintens* and *notrade*, is absent in the full model regressions of Table V. This can also explain why *borrow* is insignificant, since the only difference in the definitions of *exp* and *borrow* is the net sales in allowances.³³ There is thus no evidence that investors valued the firms' net sales of allowances, or that larger traders derive value from the fact that they are large traders, irrespective of them being buyers or sellers. Hence, both Hypothesis H.4 and H.5 need to be rejected.

In one respect it is surprising that neither net sales nor trade variables come up in the regressions. As listed firms normally manage their currency exposure, it is very probably they do that for their carbon exposure as well. As the carbon market was relatively new and carbon prices were high, one might expect that market traders could have engaged in profitable trading strategies. Although they may have done so, it had no discernible effect on share prices. According to Miclăuș et al. (2008) the futures market was already efficient, implying that good market signals were available. Nevertheless, it is also not surprising that this carbon trade effect is missing. There are few measures available for investors to gauge a firm's trade activity. Data on forwards and futures positions taken is not publicly available. And data from the Community Independent Transaction Log (CITL), the EU ETS transactions database, needs much restructuring before it is useable. Besides, the CITL data is published 5 years after an EU ETS calendar year. In some U.S. emissions trading schemes, in contrast, data on emissions is published daily and annually on the allowances transferred.³⁴ While continuous monitoring of greenhouse gases may be expensive (at least for now), there should be no technical limits on more frequent publications of the transfer of allowances. Without a view on the trade in allowances, one cannot discern whether firms complied by abating pollution or by buying allowances. This information shortage constrains markets in realizing their valuable allocation properties.

Another information constraint results from the compliance timing as laid out in the EU ETS Directives. While (currently) allowance auctions are spread over the calendar year and thus ensure a gradual feed-in of information, there is just one moment in the year that all firms need to surrender their allowances. It will thus be conducive to market certainty if there are more of such moments during the year (e.g. Holland and Moore, 2012), and that the European Commission subsequently reports on these compliance moments.³⁵ This would have prevented or at least reduced the April 2006 shock. And if signals on scarcity come too late, it becomes difficult for firms to forecast whether they have planned enough emission-reduction projects. If the release of information on the scarcity in the EU ETS is stepped up, situations of over-allocation such as the EU ETS faces currently are more likely to be averted.

³³ *borrow* is defined so that higher values point to lower (short) term holdings. If the net sales are forced to zero for all firms, the correlation between *exp* and *borrow* will equal -1.

³⁴ Continuous monitoring is mandatory for SO₂ and NO_x emissions under the U.S. Acid Rain Program. Companies need to be able to record their emissions at 15 minutes intervals. Based upon these rates the US Environmental Protection Agency publishes the hourly-average rates (e.g. see <http://www.epa.gov/airmarkets/emissions/continuous-factsheet.html>).

³⁵ While the analysis of Holland and Moore (2012) is on the Los Angeles NO_x market, i.e. on a point source type of pollution, it may be applicable to the non-point CO₂ emissions as well.

7. Conclusion

Did EU ETS firms' shareholders interpret the carbon price drop of April 2006 as significant and, if so, how did the event's impact differ among firms' allocations and transactions? To answer this central question, an event study was used. In the event study, the focus was on share price returns as different from those of a business-as-usual situation, i.e. without the event. These so-called cumulative abnormal returns (*CARs*) were derived from a sample of exchange-listed firms which took part in the EU ETS, by either having received allowance allocations, by having traded allowances, or both. The statistics of the *CARs* indicate that for most of these firms (and the EU ETS sectors these firms are part of) shareholders did interpret the event as value-relevant. For most firms and sectors the impact was considered to be negative. In that sense, the EU ETS did 'bite'.

From a theoretical perspective, there are three main channels that jointly determine the firms' share price responsiveness to the EU ETS: 1) the product market, namely the carbon-intensity of production and the susceptibility to carbon leakage, 2) the borrowing and exposure effects, namely the short term allowance holdings and the medium term allocations-to-emissions gaps, and 3) the trade in allowances, namely a firm's share in the allowance trade. Based on these channels, variables were devised and checked for their responsiveness with the firms' *CARs*.

The results indicate that the carbon-intensity of production and the medium term allowance holdings were, respectively, negatively and positively related to the firms' market valuations. These results seem to point to a longer term market perception. With future expected stringency of the EU ETS, firms are considered more competitive with lower carbon-intensity rates and larger allowance holdings as both are signals of better abatement capacities. The EU ETS is thus valued as a restriction on pollution.

The expectation with carbon-intensity was that its impact would depend on carbon leakage. This only turned out to be the case for the industry sectors of power and heat and of cement and lime. With more detailed data on the firms' pass-through of carbon costs, significance could perhaps improve for the other six ETS sectors. Furthermore, the finding of a positive relationship between *CARs* and medium term allowance holdings supported the opposite of what was theoretically expected. We expected that the carbon price drop would increase the profits for firms having allowances shortages, and would decrease profits for firms having allowance surpluses. Since we found opposite results, the market possibly incorporates a longer time horizon than expected.

Finally, the firms' trade activity in allowances was not valued in the *CARs*. This result may well be the consequence of investors lacking sufficient data on the allowance trade as conducted by firms. A valuation will then be difficult to make when it is not known whether firms complied by abating pollution or by buying allowances. The market will therefore benefit if the European Commission increases the frequency of publications of the emissions of firms and their allowance transfers.

8. References

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Authors contacts:

Thijs Jong

Ph.D. researcher, corresponding author

University of Groningen, Faculty of Law, Department of Law and Economics

P.O. Box 716, 9700 AS Groningen

The Netherlands

E-mail: m.a.p.jong@rug.nl

Telephone +31 (0)50 363 2174

Fax + 31 (0)50 363 7101

Oscar Couwenberg

Professor of Law and Economics

University of Groningen, Faculty of Law, Department of Law and Economics

E-mail: o.couwenberg@rug.nl

Edwin Woerdman

Associate Professor of Law and Economics

University of Groningen, Faculty of Law, Department of Law and Economics

E-mail: e.woerdman@rug.nl